

**BELLCOMM, INC.**

955 L'ENFANT PLAZA NORTH, S.W.

WASHINGTON, D. C. 20024

SUBJECT: Multiple Docking Adapter  
Thermal Control System  
Case 620

DATE: September 30, 1968  
FROM: J. W. Powers

ABSTRACT

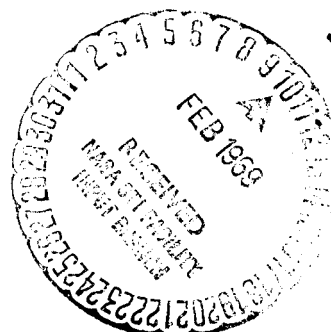
This memorandum describes the thermal control system of the Multiple Docking Adapter. Ground assembly of the Multiple Docking Adapter, Airlock Module, and Orbital Workshop brings together these major Orbital Assembly components for the AAP-2 mission. The thermal control systems for these three modules plus any docked modules are integrated through open hatches, a duct and fan system, and a common atmosphere. Passive thermal control with minimum active augmentation is employed for power-down operation. During the power-up phase, the active system of radiators and Airlock Module heat exchangers dissipates the additional heat load.

(NASA-CR-73531) MULTIPLE DOCKING ADAPTER  
THERMAL CONTROL SYSTEM (Bellcomm, Inc.)  
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MEMORANDUM FOR FILE

INTRODUCTION

Ground assembly of the Multiple Docking Adapter (MDA), Airlock Module (AM), and Orbital Workshop (OWS) brings together these major Orbital Assembly components for the AAP-2 mission. The MDA is a transitional interconnecting structure permanently attached to the AM at one end and providing docking interfaces for the CM-SM and LM-ATM at the other end. Storage area for experiments and equipment during the launch phase is provided. Certain experiments will be conducted in the MDA. The environmental control system (ECS) of the AM and thermal control systems of the listed orbital assembly components are integrated through open hatches, a system of ducts and fans, and a common atmosphere. Thermal control of the orbital assembly is primarily passive with active augmentation by the AM ECS, fans, and heaters.

MDA THERMAL CONTROL REQUIREMENTS

Thermal design requirements for the MDA are:

1. Cold conditions

- . Maximum passive heat loss, 243 Btu/hr. (71 w)
- . Minimum internal wall temperature, 50°F
- . Average wall temperature,  $\geq 60^{\circ}\text{F}$

2. Hot conditions

- . Maximum internal heat generation, 1250 Btu/hr.\* (366 w)
- . Maximum internal wall temperature, 90°F

3. Crew atmosphere comfort criteria

- . Circulation velocity,  $\geq 15$  ft/min. and  $\leq 100$  ft/min.

Maximum internal wall temperature is based upon astronaut touch limits, and the minimum internal wall temperature is based upon moisture condensation considerations.

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\* Crew metabolic heat rates not included.

MDA THERMAL CONTROL

MDA internal thermal control is achieved using the common atmosphere as the primary heat transfer medium. The passive thermal control system insulates the MDA volume to maintain a minimum temperature during the power-down phase with minimum heater augmentation. During the power-up phase active thermal control dissipates the additional heat load.

The combined thermal control systems and the AM ECS perform the following functions to achieve the requisite "shirt-sleeve" environment for the orbital assembly: Maintenance of a comfortable internal temperature, prevention of large amounts of water vapor condensation, maintenance of internal atmosphere velocity relative to crew comfort, and purification and dehumidification of the internal atmosphere. A single O<sub>2</sub>-N<sub>2</sub> atmosphere (3.7 psia O<sub>2</sub> partial pressure and 5.0 psia total pressure) is common to the MDA-AM-OWS plus any docked modules. The atmosphere is supplied after docking from gases stored in the Service Module. After docking of the CM-SM and pressurization of the MDA-AM-OWS, commonality of the orbital assembly atmosphere is maintained through open docking ports and a system of fans and ducts. Operation of the ECS on these docked modules thus contributes to overall thermal control. The AM ECS located in the structural transition section (STS) performs the CO<sub>2</sub> removal, humidity control, and particulate matter and odor removal functions for the common atmosphere.

Incident external thermal loads are primary functions of the vehicle geometry, orbital parameters, vehicle orientation relative to earth, orientation of earth relative to sun, and vehicle coatings properties. Internal heat liberation is caused by the astronauts' metabolic rates, fans, heaters, lights, equipment and experiment outputs. Excessive sensible and latent heat resulting from the external and internal loads are removed from the atmosphere by the three cabin heat exchangers and the two condensing heat exchangers located in the STS. The MDA thermal control system components are radiators, coolant lines, ducts, fans, heaters, insulation, and thermal coatings. Major MDA thermal system components are discussed below. Figure I shows the external MDA configuration, and Figure II is a schematic of the MDA thermal control system.

PRESSURE SHELL STRUCTURE

The cylindrical pressure shell structure of the MDA is fabricated from 2219 aluminum alloy with a basic thickness of 0.076 in. Eight equally-spaced chemically milled local external longitudinal lands 0.25 in. thick provide areas for exterior structural attachment of both the radiator and meteoroid shield.

INSULATION

The MDA's pressure vessel outer surfaces are covered with a high-performance, multi-laminar, insulation blanket approximately one inch thick. This blanket, which also provides some meteoroid protection, consists of 27 layers of double aluminized mylar film 0.003 in. thick. Individual film layers within the blanket are separated with 0.020 in. thick polyurethane foam spacer sheets slightly larger in area than the mylar. Outer facings of the blanket are thin porous fiberglass sheets. Cord tension ties connected to the facing sheets hold the insulation blanket together while the alternating foam sheets maintain the mylar film spacing. Design conductivity of the insulation blanket is  $5 \times 10^{-4}$  Btu/hr ft<sup>2</sup> °R. The extremely low conductivity of this radiation barrier type high performance insulation is dependent upon an internal vacuum to limit the gas conduction heat transfer mode. This vacuum is achieved by venting the insulation to the local space environment through both the tension tie holes and the edge butt joints and finally through the porous outer facing sheet. A dry N<sub>2</sub> gas prelaunch purge of the insulation system is required to minimize internal moisture within the blanket. A system of manifolded perforated aluminum tubes attached to the outer surface of the MDA Pressure shell routes the dry purging gas under each installed insulating blanket. Significant increases in conductivity are experienced with this type of insulation under conditions of increasing temperature, increasing internal pressure and blanket thickness compression. Insulation installation will be accomplished by utilizing rectangular panels approximately 2.5 ft x 7.0 ft. which are bonded to the MDA pressure shell and then laced together at the edges with nylon cord. Individual butt joints between panel segments are formed by compression of the slightly oversize spacer foam sheets at the blanket edges. Joint design requires slight compression of the foam with no contact between the multiple aluminized mylar sheets of adjacent blankets. Figure III shows the details of the insulation attachment and meteoroid shield connection to the MDA pressure shell.

Attachment of the insulation blankets to the outer surface of the MDA pressure shell presents potential design and installation problems for the following reasons:

- . The blanket size (2.5 ft x 7.0 ft) is small compared with the total area to be insulated, thus requiring many individual adhesive bonding operations and many linear feet of total joint length.
- . The installation must provide for rapid decompression of the blanket when exposed to the local vacuum space environment.

- . Blanket installation procedure may cause a thickness compression with an attendant increase in thermal conductivity.
- . The insulation blankets must be accurately trimmed and fitted around the many required protuberant structural elements.
- . The individual blankets must be bonded to the landed outer pressure shell over the purge gas tubes. The bonding of adjacent blankets must allow slight edge compression of foam sheets but no contact of mylar film for minimum parallel heat flow. Since the blankets are relatively soft, precise gauging by tooling will be difficult. Maintaining the requisite optimum location of adjacent insulation blankets will be a difficult problem with many process variables.

Penetrations of the basic insulation blanket provide major paths for heat transfer since the extremely low conductivity blankets must be trimmed to conform to the geometry of the protrusion. Discontinuities and penetrations degrade the thermal performance of the highly anisotropic multi-laminar insulation systems. Three docking ports, two windows, vent lines, electrical feed through connections, and hundreds of structural connections for the radiator and meteoroid shield penetrate the high performance radiation barrier insulation. These components provide the areas of major heat loss in the MDA structure. Heat losses for the docking ports and windows are reduced by use of removable insulating covers. Fiberglass structural members are used to limit heat transfer between the welded tabs on the MDA pressure shell and the connections on the radiator and meteoroid shield.

The complex nature of the required three dimensional thermal analysis for these penetrations renders even the most assiduously performed computer aided analysis a first approximation. TV\* module testing is being used to verify the insulation & penetration analysis. A full scale MDA-AM integrated TV-test could establish the overall capability of the combined ECS and thermal control systems.

#### RADIATOR

The lateral surface of the insulated MDA cylinder between the STS attachment face and the transverse docking ports is covered with a cylindrical ECS radiator that provides the major portion of the available radiator surface of the MDA-AM-OWS orbital assembly. This radiator, which consists of primary and secondary loops isolated from each other, also functions as a meteoroid shield. A similar radiator of reduced cylindrical height is attached to the AM adjacent to the MDA radiator at the MDA-AM interface. Primary and secondary elements of the MDA and AM radiators are connected together. Heat

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\* Thermal vacuum.

rejection capability of the MDA radiator while in a shadow is 10,780 Btu/hr and while in the sun is 8,400 Btu/hr. The radiator coolant fluid is MMS 602 (Monsanto No. 15). Radiator sizing and thermal characteristics are based upon heat rejection requirements during orbital orientations of maximum heating at which time the radiator is least efficient. White paint ( $\alpha/\epsilon = 0.2/0.875$ ) applied to the radiator outside surface yields the desired heat rejection characteristics.

Radiator stand-off annular distance measured from the MDA pressure shell O.D. to radiator cylinder O.D. is approximately 2.65 in. The radiator cylindrical shell is fabricated from 0.032 in. thick magnesium alloy sheet with tubular fluid lines attached to the undersurface. Radiator and meteoroid shield structural attachment is provided by circumferential flanges and aluminum tabs welded to the locally thickened MDA pressure shell. Fiberglass thermal standoffs connect the radiator to the pressure shell structure.

#### METEOROID SHIELD

The MDA conical surface and that portion of the cylindrical surface not covered by the radiator are covered by a meteoroid shield. Stand-off distance of the meteoroid shield is approximately the same as that of the radiator. This shield is fabricated from 0.02 in. thick 2024 T3 Aluminum alloy and is attached to the pressure shell by fiberglass thermal standoffs in a manner similar to the connections of the radiator.

#### THERMAL COATING

In an inertially oriented spacecraft with passive thermal control, the equilibrium temperature is established by selection of coatings\* with appropriate absorptivity/emissivity ( $\alpha/\epsilon$ ) ratios and their areas of application. Passive control of heat rejected through the MDA cylinder is achieved by selection of outer and inner surface coatings of meteoroid shield and outer coating of cylinder insulation. Black paint ( $\alpha/\epsilon = .95/.86$ ) is applied to the outside surface of the meteoroid shield. Low emissivity coatings ( $\approx 0.05$ ) are applied to the inside surfaces of the meteoroid shield and radiator and outside surface of the MDA cylinder insulation. Low emissivity coatings on both surfaces of the annular volume between the insulation O.D. and meteoroid shield and radiator I.D. limit the absorption or rejection of heat by radiation in a manner similar to a silvered vacuum flask. The sensitivity of the MDA to the external environment is thus greatly reduced.

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\*For a single coating the equilibrium temperature is  $\sim (\alpha/\epsilon)^{1/4}$

Stability of the spectral properties of thermal coatings is an important consideration in any spacecraft which employs passive or semi-passive thermal control. Degradation (increase) of coating absorptivity from long time exposure to the ultraviolet space environment has caused significant temperature increases in previous spacecraft. Some stable low absorptivity white paints used in space applications will experience approximately 20% degradation in absorptivity during missions of AAP Orbital Assembly duration. If a passive spacecraft utilizes paint of absorptivity 0.20 and a 20% coating degradation occurs, the corresponding temperature increase to a 70°F design temperature will be approximately 26°F. For a lesser percentage degradation, the temperature increase will be proportional to the increase in absorptivity.

To ensure that contamination of experiment data does not occur, thermal coatings must be evaluated for possible vacuum outgassing. Paints are also difficult to apply reproducibly and this problem, of course, increases in proportion to the surface area to be coated. Thermal coatings can also be contaminated during the launch phase. This effect on the MDA and AM should be minimized by the protection provided by the jettisonable aerodynamic shroud. The effects of launch phase environment on thermal coatings is one of the AAP experiments (M415). Coating contamination during assembly and handling is also possible.

#### DUCTS

Atmosphere circulation within the MDA by the AM ECS is accomplished through three 6-inch dia. ducts (150 cfm/duct) and one 4-inch dia. duct. Conditioned atmospheric gas from each of the STS cabin heat exchangers is directed through a 6-inch diameter duct. The 4-inch dia. duct is also utilized for drying the stored astronaut EVA suit. The atmosphere for this duct passes either through the LiOH canister or the molecular sieve for CO<sub>2</sub> removal. These four ducts discharge scrubbed conditioned atmospheric gas into the MDA near the forward (conical) end. Two additional 6-inch dia. flexible exhaust ducts, one for the axial port and the other for either radial port, provide atmosphere circulation for docked modules. These two ducts terminate near the MDA-AM interface and are open to the local internal atmosphere at this location. Makeup atmospheric gas to replace that lost by leakage and crew consumption is supplied through the CM N<sub>2</sub> and O<sub>2</sub> regulators.

#### FANS

Eight Gemini-type two-speed post landing ventilation fans provide a maximum MDA atmosphere circulation capability of approximately 700 cfm. Fan assemblies for the two drag in docking port ducts include mufflers, handles and quick disconnects.

Atmospheric flow rate from fan operation is a function of the internal temperature and pressure and supply voltage. Six of the fans are mounted in the supply ends of the ducts listed in the previous paragraph. The other two fans are not mounted in ducts and are at the conical head of the MDA close to the discharge ends of the three 6-inch dia. ducts. The fans for the three 6-inch dia. ducts are each mounted in the STS adjacent to a cabin heat exchanger. The fan for the suit drying duct is also in the STS. Typical flow rates for high and low speed fan operation @ 70°F are 150 and 100 cfm.

#### HEATERS

Heaters are required to increase the pressure shell temperatures prior to activation of the MDA after orbital storage. Longitudinal electric strip heaters will be provided at eight evenly spaced circumferential locations on the inside surface of the MDA pressure shell. Two 20 watt heaters will be bonded to the wall at each of the 8 locations and extend the full length of the MDA cylinder. Control of these 16 heaters will be by ground command with a crew override provision. Thermostatically controlled surface heaters of the same type will be provided, as required, around the periphery of windows, docking ports and other penetrations of the basic insulation shell.

#### ACKNOWLEDGMENT

Some of the included data were kindly provided by Mr. J. L. Vaniman, MSFC, R-P&VE-PTD. Responsibility relative to any errors in recording, interpretation, or evaluation is, of course, solely the author's.

*J. W. Powers*

1022-JWP-ms

J. W. Powers

Attachments.

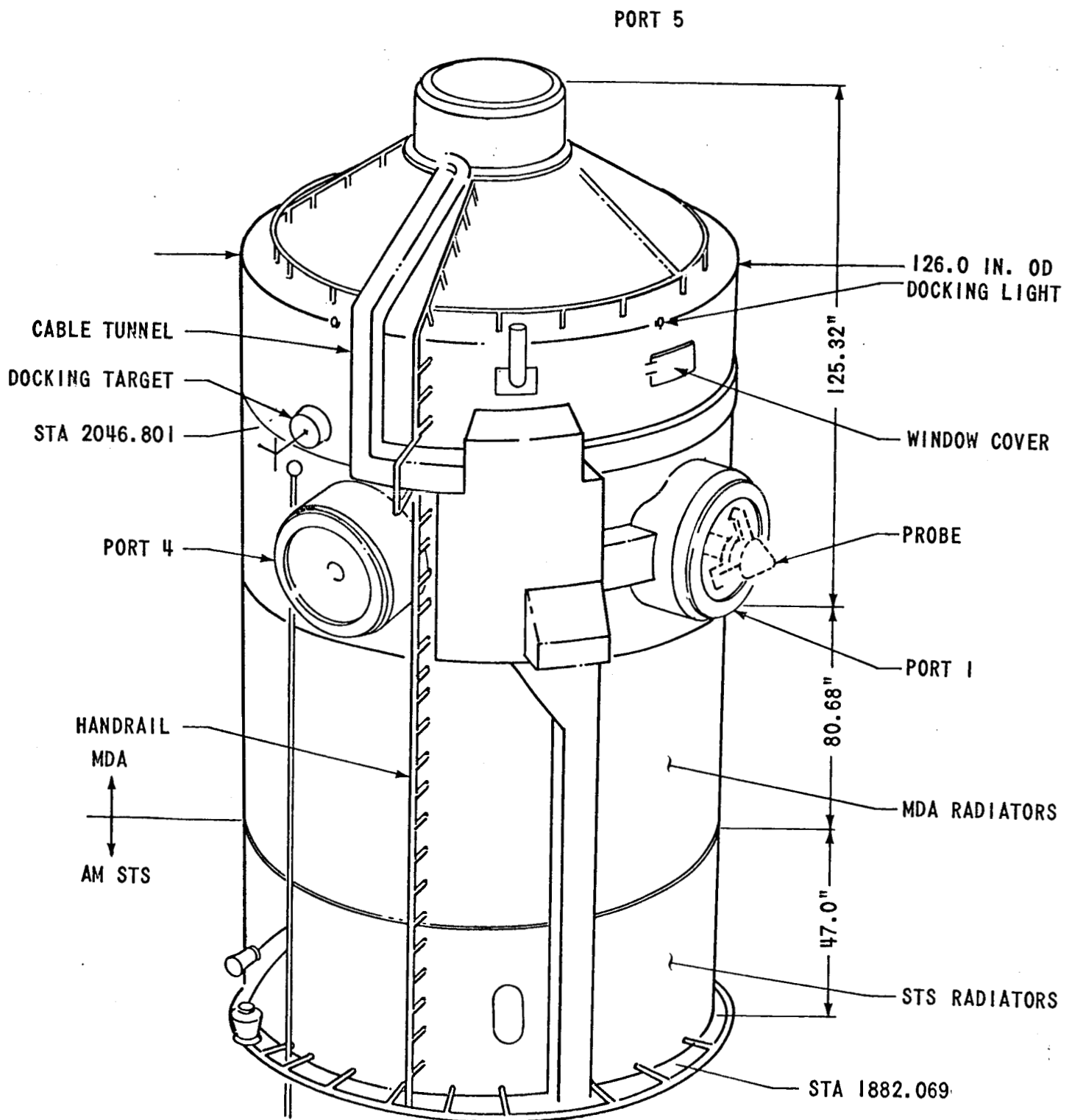


FIGURE 1 - MDA EXTERNAL PROFILE

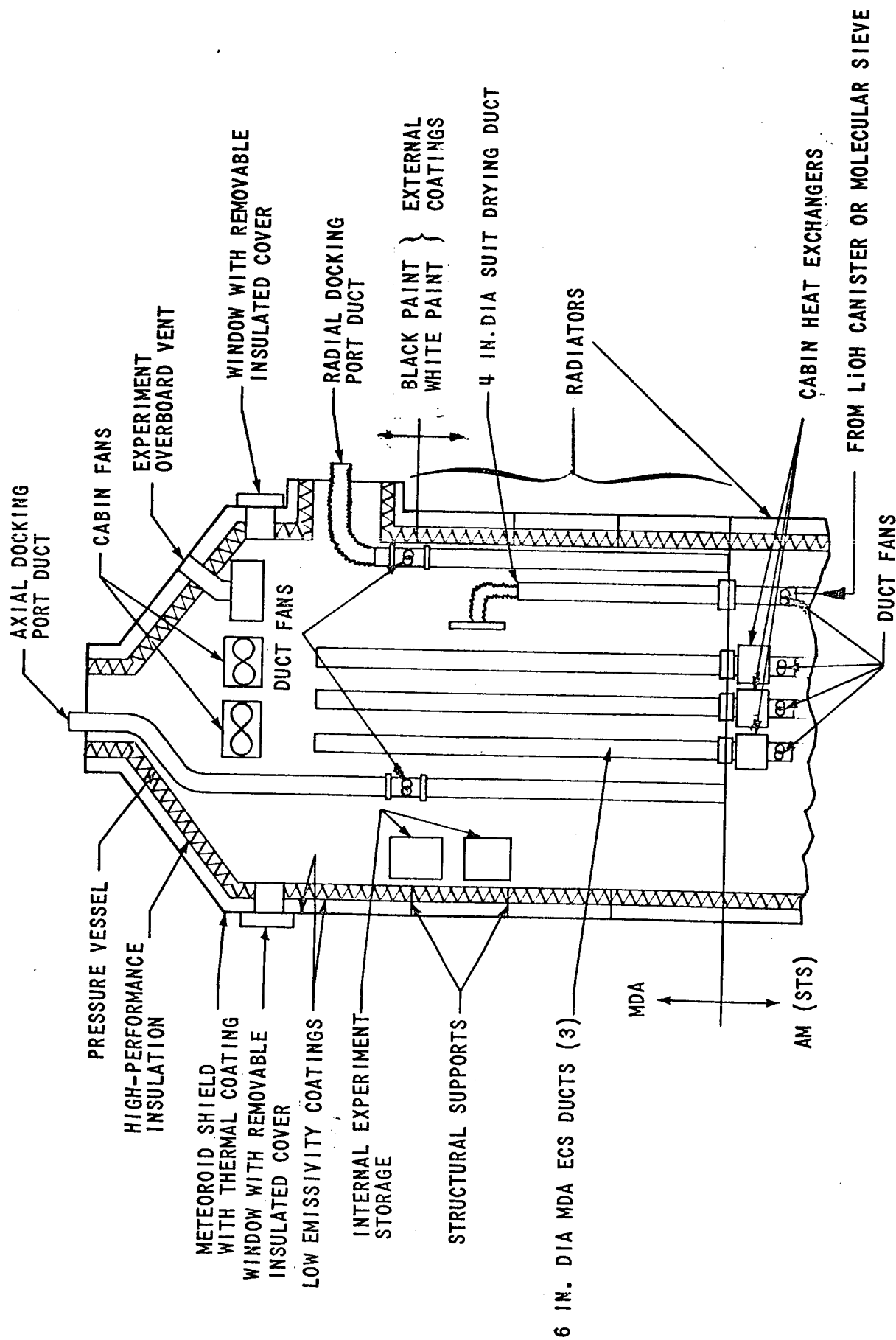


FIGURE 2 - MDA THERMAL CONTROL SYSTEM SCHEMATIC

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1. NASA, Cluster Systems Description Document, Vol. I, .  
MSFC, ED 2002-452, July, 1968.
2. NASA, Data Package Multiple Docking Adapter Fluid Systems,  
MSFC, R-P&VE-PMD, December 14, 1967.

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**DATE:** October 8, 1968

**FROM:** J. W. Powers

**To:** Distribution

Attached Figure 3 was inadvertently left out of the subject memorandum, dated September 30, 1968. Please attach to your copy.



J. W. Powers

1022-JWP-ms

Attachment  
Figure 3

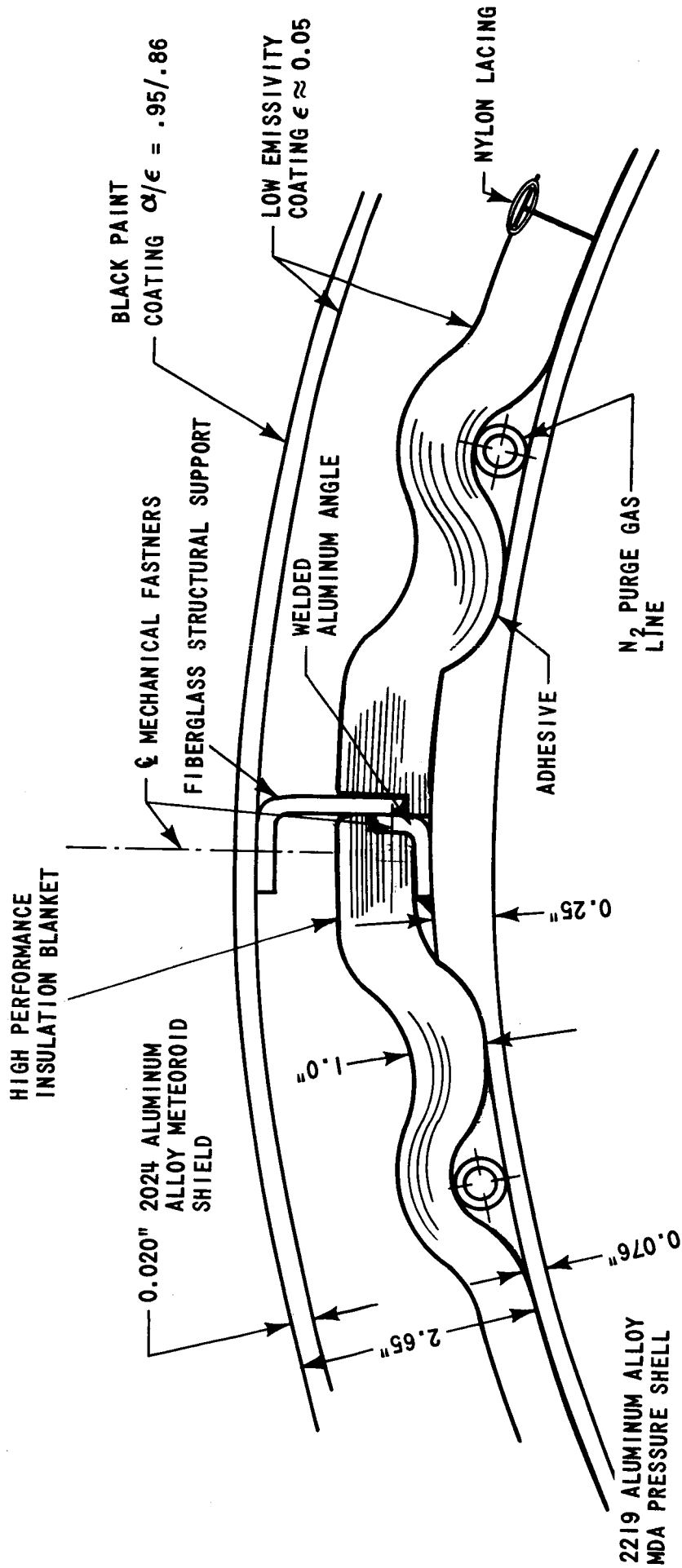


FIGURE 3 - SCHEMATIC MDA METEOROID SHIELD STRUCTURAL CONNECTION & INSULATION INSTALLATION

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